LX. Haptical Illusions of Movement

By William A. Andrews

The present study was suggested by Benussi's results in his experiments on the tactual illusions of movement.[1] Benussi, thinking to duplicate in the field of touch Wertheimer's work in vision,[2] stimulated successively two spots on the skin separated by distances ranging from 4 to about 170 cm. (the distance between the finger-tips with outstretched arms) and by times ranging from 160 to 2200 σ. He obtained, among other kinds of movement, a "bow" movement, which his *Os* described as the movement of 'something' up from the skin through the air and down to the second point touched, "eine Bogenbewegung in der Luft."[3]

The object of the present investigation was two-fold: (1) to determine the optimal conditions under which this kind of movement appears; and (2) to describe the experiences in strictly psychological terms and to identify, if possible, the existential correlates of the 'something' which moved away from the skin.

Observers.—The *Os* were: Dr. J. M. Gleason (G), assistant professor of psychology at Vassar College; Dr. Karl M. Dallenbach (D); and Mr. W. A. Thalman (T), graduate student in psychology. G and D were highly practised in cutaneous observation; T, though trained in introspection, had not observed before in a cutaneous experiment. G and T worked without knowledge of the problem other than that given them in the instructions. All the *Os* observed an hour a day, six days a week, and so far as possible at the same hour every day. The experiments were performed during the Summer Session of 1921.

We first sought to obtain the 'bow-movement' and to determine the optimal conditions under which it appeared. Our idea was to secure these results in a series of preliminary experiments and then, using the optimal conditions, to turn in the main experiments to the problem of description.

Preliminary Experiments

In the preliminary experiments the following instructions were read to the *Os* at the beginning of every experimental hour: "At 'Ready, Now' your forearm will be stimulated. Characterize fully the cutaneous perceptions aroused, using any common-sense terms you wish."

Apparatus and Procedure.—In these experiments the volar surface of the left forearm for D and T and of the right for G was stimulated by two successive pressure points. The arm was smoothly shaved and held comfortably in a fixed position by a plaster cast. A modified form of Benussi's kinohapt[4] was used in applying the stimuli. In order that no distracting temperature sensations should be aroused, the pressure points were made of hard rubber. The diameter of the rounded tips was 1 mm. An area of approximately 0.8 sq. mm. was therefore stimulated whenever the points were applied to the skin.

The stimuli were successively applied along (or parallel to) the longitudinal axis of the arm. The second stimulus was always peripheral to

[1] V. Benussi, Kinematohaptische Erscheinungen, *Arch. f. d. ges. Psych.*, 29, 1913, 385; Kinematohaptische Scheinbewegung und Auffassungsumformung, *Ber. ü. d. VI. Kong. f. exp. Psych.*, 1914, 31; Versuche zur Analyse taktil erweckter Scheinbewegungen, *Arch. f. d. ges. Psych.*, 36, 1916, 59.

[2] M. Wertheimer, Ueber das Sehen von Bewegung, *Zeit. f. Psych.*, 61, 1912, 161 ff.

[3] *Ber. ü. d. VI. Kong. f. exp. Psych.*, 1914, 32.

[4] *Arch. f. d. g. Psych.*, 29, 1913, 385 ff.

the first. Before every experiment the pressure points were carefully set by a fine adjustment to a distance of 0.5 mm. above the surface of the skin. The current operating the kinohapt, which was controlled by a shunted rheostat, was checked several times during an observational hour. The strength of the current was constant; only a few times during the entire experiment did the milliammeter show a variation. Since the excursion of the pressure points and the strength of the current were constant, the intensity of the stimulus may likewise be regarded as constant.

The kinohapt was controlled by a Leipzig time-sense apparatus, driven by a Ludwig-Baltzar kymograph. The duration of each stimulus was 150 σ. The temporal intervals between stimuli were 100, 600, 1100, and 1600 σ; and the spatial intervals were 2, 6, and 10 cm. Each stimulus was applied but once; that is, there was but one application of the bi-membral stimulus during a single experiment[5]. The experiments were performed in series of 10. Every temporal interval was used in haphazard order with every spatial interval. At the end of 12 groups, which this procedure necessitated, the experiments were continued by reversing the order; the 13th series was like the 12th, the 14th like the 11th, etc. The practice-effect was thus evenly distributed throughout the series. Two precautions were taken to guard against fatigue: (1) the pressure points were moved to new areas after every experiment; we were careful not to stimulate the same point twice during a single hour; and (2) at the end of every series *O* rested his arm a few minutes by taking it from the cast. Usually three series of 10 experiments were conducted during an experimental period. Since 20 reports were given for every combination of the variables, a total of 240 reports was obtained for every *O*.

Results.—G and T did not report movement phenomena of any kind. Their experiences were described as two completely independent impressions. They characterized the impressions, localized them, mentioned the temporal sequence, etc., but never reported movement, or anything that could be interpreted as movement. D, on the other hand, reported the phenomenon in about 45% of the experiments. His movement reports were of three kinds:

(1) *Unimembral.*—One member was perceived as moving; sometimes it was the first, and sometimes the second. When the movement was at the first it was always in the direction of the second; when it was localized at the second, two types were distinguished: (*a*) the movement was in a peripheral direction away from the first; and (*b*) the movement was in a central direction toward the first. Examples are: "Two touches, second peripheral to first. First one seems to move toward second." (100σ, 6 cm.) "First one seemed to be stationary and second seemed to fly off." (1600σ, 6 cm.) "Second seemed to jump backwards toward first." (600σ, 6 cm.)

(2) *Bimembral.*—Both members moved. Two types were reported: (*a*) both members moved from points of rest; and (*b*) the first moved from a point of rest, and the second to a point of rest. Examples are: "Two touches which seemed to rebound from the skin." (1600σ, 2 cm.) "Touch left skin and landed peripherally about 3 inches away, partial loop, not complete at top of arc." (1600σ, 2 cm.)

(3) *Full movement.*—The movement was complete from the first point to the second. Two types were described: (*a*) the first impression "hopped," "skipped," or "jumped" to a new position; and (*b*) the first impression, "slid," "glided," or "was dragged" to a new position. Cases of the

[5]This procedure we knew to be at variance with Benussi's; we adopted it, however, as we thought that the repetition of the stimulus would give rise, through suggestion, to subjective conditions. We were desirous in these experiments of restricting our investigation to objective conditions.

second type occurred infrequently; only 6 cases were reported during the preliminary experiments. Examples of these two types are: "First jumped to new position, complete arc." (100σ, 2 cm.) "Touch which glided on surface of skin to new position." (100σ, 2 cm.)

The reports in which no movement occurred were of two kinds. (*a*) The impressions, though discrete in time, were localized at a single spot, as: "Two touches, seems as if the same spot was touched twice." (1100σ, 6 cm.) (*b*) The impressions were discrete in space as well as in time, as for example: "Touched twice in very rapid succession, points discrete, second peripheral to first." (100σ, 6 cm.)

Since the objective conditions were constant throughout the experiments, and since D and G were about equally proficient in cutaneous observation, we believe that the difference between the reports of D and those of G and T, in regard to the perception of movement, is due to a difference of attitude. It is certain that the subjective conditions were not the same: G and T, as we have said before, worked without knowledge of the problem; they approached the experiments naively; whereas D, who was familiar with the problem and knew the object of the present research, was set for movement. This fact was clearly established by one of D's early reports, in which he said, after characterizing the "bow" movement: "I am attending to the stimulus, I am set for movement, and an effort is made to obtain it." Under this attitude, which we shall call the "meaning"attitude, the objective conditions were at times sufficient to give rise to perceptions of movement; but under the attitude which G and T assumed, the objective conditions were never sufficient to produce the perception.

Though the object of the preliminary experiments was thus defeated, —optimal conditions for a 'bow' movement were not obtained,—the results are significant. They show that objective conditions are alone not adequate to the perception of movement; that we are dealing with a perception which is in part dependent upon subjective conditions;[6] and that we must establish the "meaning" attitude if we are to parallel Benussi's results.

Two methods of establishing the proper subjective conditions immediately suggested themselves: the one, a direct method, was to give the suggestion openly in the instructions by telling the *O*s what we wished them to attend to; the other, an indirect method, was so to cut the objective conditions that the suggestion would come from these themselves. For obvious experimental reasons the latter method was chosen for the Main Experiments.

Main Experiments

Procedure.—The procedure was altered in but one respect: the bimembral stimulus was applied in every experiment a number of times in rapid succession.[7] The time-interval between every two pairs was twice the length of the interval between each member of the pair. That is, when the temporal interval between the members of a pair was 100σ, the temporal interval between the pairs was 200σ, etc. We thought that this procedure would strengthen the association between the members of a pair, and that it would through expectation and habituation lead to the suggestion of movement. In order that the effect of this multiple stimulation might be the better observed and the formation of the meaning attitude (if such an attitude were formed) might be the better studied, the pairs were

[6]This agrees in substance with the conclusions of Whitchurch (A. K. Whitchurch, The Illusory Perception of Movement on the Skin, this JOURNAL, 32, 1921, 486 f.).

[7]This is evidently the procedure that Benussi used, though he is not explicit,—he does not tell us, for example, how many times the pairs were applied or what time-intervals elapsed between the pairs.

applied 5, 10 and 15 times in succession. Every temporal and spatial interval mentioned in the preliminary experiments was used 5 times in haphazard order with every one of these multiple stimulations: thus, a total of 180 experiments was performed for every *O*.

Instructions.—The instructions were extended to include process as well as meaning. "Two points on your arm will be stimulated in rapid succession. When I say 'now' (which was said after 5, 10, or 15 repetitions) (*a*) characterize fully in any common-sense terms you wish the cutaneous perceptions aroused and (*b*) describe the perceptions in purely psychological terms." 'Process' instructions were added partly because we thought that they would indirectly, as if by contrast, assist in the establishment of the subjective conditions necessary to the realization of the movement perception, and partly because we still hoped to obtain the existential correlates of the illusory movement.

Results.—Our attempt to establish thus indirectly the necessary subjective conditions was on the whole successful. All the *O*s reported illusory perceptions of movement. D reported movement of some kind in approximately 80% of the experiments, G in 92 %, and T in approximately 22%.

In addition to the perceptions reported in the preliminary experiments, D reported four new types.

(1) A new type of bimembral movement was reported, in which each point moved a short way in the direction of the other, as for example: "Two touches, each seemed to jump part way toward the other." (1100σ, 10 cm., 10 rep.) (2), (3), and (4). Three new types of full movement were reported. In one the movement was backward, from the second to the first; in another the movement was alternately forward and backward; and in the third the movement was double, two arcs diverging from one central point to two peripheral points. Examples are: "..... Movement reversed and appeared to go backward, that is centrally." (600σ, 2 cm., 15 rep.) "Movement back and forth between the two points touched." (1600σ, 10 cm., 10 rep.) "Peripheral loop movement seemed to end at two different points." (1600σ, 2 cm., 15 rep.)

Though G reported movement phenomena in 92% of the experiments, she reported but two kinds of movements: unimembral movement, and full movement. Only two cases of unimembral movement were reported, and they were both of the same type; the first member moved in the direction of the second. These cases are: "Two touches, upper flicked off." (1600σ, 6 cm., 5 rep.) "Two successive touches, first flicked off in direction of the second." (1600σ, 6 cm., 5 rep.)

In 91% of the experiments G reported full movement. She distinguished four types. (1) The movement was from the first to the second; when of this type it took at times the form of an arc, bow or loop, as for example: "Pair of touches, hopping from point to point, always forward not backward." (100σ, 6 cm., 15 rep.). At other times it was on or in the skin as: "Movement peripheral, slid on skin to position of second touch." (100σ, 10 cm., 10 rep.)

(2) The movement was backward from the second to the first, as for example: "Direction of movement veered and went backwards. Backward movement does not come in until series has run for some time." (600σ, 2 cm., 15 rep.)

(3) The movement was alternately forward and backward, as: "Back and forth arc over arm touching it in two points." (600σ, 6 cm., 10 rep.)

(4) The movement was double, diverging in two arcs from a central point to two peripheral points. "Three touches, one central and two peripheral; meaning of movement from central to peripheral points in two diverging arcs." (1600σ, 2 cm., 10 rep.)

In the experiments in which no movement was reported, G characterized the experiences as "discrete temporally and spatially." In most

cases only two impressions were described, but in a few experiments three discrete points were reported, one central and the other two peripheral,—the static equivalent of the double movement mentioned above. "Three discrete touches, one central, two peripheral. One of the peripheral was like the central, the other was sharper. No movement of any kind." (1600σ, 2cm., 10 rep.)

T, like D, reported three kinds of movement: unimembral, bimembral and full movement.

(1) Five types of unimembral movement were reported; in two the movement was localized at the first member, and in three the movement was localized at the second. When it was localized at the first member it at times left the skin, as: "First point jumped toward the second. Very definite, about half an inch." (100σ, 6 cm., 15 rep.) At other times it seemed to be in or on the skin, as: "Spread or slid down arm in direction of second." (600σ, 10 cm., 10 rep.) When the movement was localized at the second member it at times left the skin, as: "Jumping from the second toward hand, movement very definite." (600σ, 10 cm., 10 rep.) At times it seemed to be in or on the skin, as: "Second point seemed to creep on." (100σ, 6 cm., 5 rep.) At other times it seemed to penetrate the skin and go into the tissues beneath, as: "Second point appeared to move toward a third point deep under the skin."

(2) Two cases of bimembral movement were reported, in which both members of the bimembral stimulus seemed to move, as: "Both points seemed to float off the skin." (1600σ, 10 cm., 5 rep.)

(3) Though but 6 cases of full movement were reported,[8] two types were characterized. In the first the movement was in the form of an arc from the first to the second member, as: "Succession of arcs moving from the first to the second." (1600σ, 10 cm., 10 rep.) In the other the movement was subcutaneous, as: "Subcutaneous movement which went successively from the first to the second." (1600σ, 10 cm., 10 rep.)

The most favorable conditions of the illusory perception of movement differ greatly for the several observers. The optimal temporal interval is 100σ for D, 1100σ for G, and 1600σ for T; the optimal spatial interval is 10 cm. for D, 6 cm. for G, and 10 cm. for T. The only variable moment that the *O*s agree upon is repetition; a greater percent. of movement phenomena is reported with 15 repetitions than with either 10 or 5 repetitions, and a greater percent. is reported with 10 repetitions than with 5.

The conditions most favorable to movement in general are also, for G and T, the conditions most favorable for the bow or loop movement,[9] but for D a different array is shown: the optimal temporal interval for bow movement is 600σ as opposed to 100σ; and the optimal spatial interval is 2 cm. as opposed to 10 cm. As before, however, 15 repetitions are the most compelling.

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[8]In an effort to increase the number of bow movements, a supplementary experiment was conducted with T after the completion of the Main Experiments. The apparatus and procedure were the same as before, except that every temporal interval was used but once with every spatial interval, and that the stimuli were repeated 15 times in every experiment. The direct method of establishing the subjective conditions was used. We told T, in the following instructions, what we wished him to attend to: "Benussi obtained in his work upon the illusions of movement a loop or bow effect; that is, the first impression seemed to jump through the air to a new position, the position of the second stimulus. In the subsequent experiments, attend for this perception." Under these conditions T reported full bow movement in every experiment.

[9]This result would necessarily follow for G, since most of her reports were of the arc or bow type.

Compulsory conditions were not obtained for either D or T, but were variously obtained for G. No matter, within our limits, what temporal or spatial intervals separated the two stimuli, G reported movement in every experiment when the bimembral stimulus was repeated 15 times. G also reported movement in every experiment when the stimuli were repeated 10 times at the spatial interval of 2 cm. and the temporal interval of 1100σ, at the spatial interval of 6 cm. and all the temporal intervals, at the spatial interval of 10 cm. and the temporal intervals of 100, 1100, and 1600σ; when the stimuli were repeated 5 times at the spatial interval of 2 cm. and the temporal intervals of 100 and 600σ, at the spatial interval of 6 cm. and the temporal intervals of 600 and 1100σ, and at the spatial interval of 10 cm. and the temporal intervals of 100, 1100, and 1600σ.

The fact that there is so great a diversity in the results indicates that the perception of movement haptically aroused is not primarily dependent upon objective conditions. The essential requirements seem to be that the *O*s shall have the idea of movement and that this idea be given time for realisation. This conclusion is confirmed by the fact that the more frequently the stimuli are repeated, the more frequently are movement phenomena reported; and also by the fact that the *O*s in their introspective reports trace the gradual development of the perception from discrete points through unimembral and bimembral movement to complete or full movement. Examples are:

(D) "Bow is not complete at first, but with every successive stimulation it became more so until at the end it was complete." (15 rep.)

"At first bimembral movement. By concentrating on first member and by holding it in consciousness, complete arc movement resulted." (15 rep.)

"At start of experiment the impressions discrete; then first impression seemed to move, the second remaining static; then movement appeared at second; then movement was carried across in arc." (15 rep.)

"Character of movement changed during the course of the experiment. At first, first member moved; then second; then, forward arc movement; then backward arc, at which point the experiment ended." (15 rep.)

"At first bimembral movement. With successive stimulation the break or gap in the loop became smaller and smaller until just before the experiment ended the loop was completed." (15 rep.)

(G) "Discrete at first, then grouped in pairs, and then after a few stimulations got back and forth swinging notion of object touching arm at two points." (15 rep.)

"Meaning grew up after few stimuli had been given." (15 rep.)

"Two perfectly discrete touches; then the first one had a little tail which seemed to move on the skin in direction of second; then arc movement appeared....." (15 rep.)

"At first touches punctiform, then after a while got arc movement between the two points." (10 rep.)

(T) "Movement very definite toward end of experiment." (10 rep.)

"Very slight at first, became stronger toward end." (10 rep.)

The conclusion that haptical movement phenomena are subjectively conditioned is further borne out by the processual results. The dual instruction, to note meaning and process and to give a full report of both, laid a difficult task upon the *O*s, with the consequence that the descriptions of process were frequently sketchy and incomplete. Yet, sketchy and incomplete as the descriptions are, an analysis reveals the following:

(1) The arc, loop, or bow movement, whether unimembral, bimembral or full, is a meaning added to the primary pressure sensations.

(D) "Loop movement, high and rapid. Attending for the movement. When I attend to the sensations the movement disappears and I have only two neutral pressure sensations in consciousness. Movement best obtained by falling into stimulus-error."

(D) "Movement in high arcs. If I attend to the pressure sensations I do not get the arcs, just discrete pressures."

(G) "Movement in high arcs. If I attend to the pressure sensations alone I do not get the arcs, just discrete pressures."

(G) "Got the idea of movement in arcs simply through eye kinaesthesis. When I inhibit this and attend to the pressure sensations, get punctiform pressures, perfectly discrete."

(G) "Two touches and an arc movement between them. Movement is not given in experience, it is inferred. Course of movement can be imaged in either direction."

(G) "Back and forth movement, inferred from visual and thoracic images. As far as experience goes there are simply two pressures."

(2) The processes which carry this meaning differ for the different *O*s, and for the same *O* at different times. At times the accruing processes are visual, at times they are kinaesthetic, and at other times a composite of the two, as the following examples show:

(D) "The pressure sensations are accompanied by visual images of line-like loops which are grey in quality like the grey of a pencil mark on white paper. This grey is weak at first, but it becomes stronger and more distinct as the experiment progresses. The bow was not complete at first, but with every successive stimulation it became more complete, until the arc was united in imagery. Visual images became clearer and more complete. Coordinate with this, vague and indefinite kinaesthetic sensations or images of head and eyes moving back and forth in rhythm with the stimulation."

(D) "Complete loop, very high and rapid. The cue for movement came from the changing pressure gradient and the meaning given by the visual and kinaesthetic imagery which supplemented it. The visual imagery was of a loop greyish in quality, much like the grey mark of a pencil on white paper. Kinaesthesis of eye movements along arc of this loop; think there were also kinaesthetic movements of nodding of head in rhythm of movement."

(G) "Discrete at first, then grouped in pairs, then peripheral arc movement. Positive of movement, it is there, but there is no sensory basis; given entirely by visual image of an arc with its terminals on the skin."

(G) "Backward movement, 2-1, meaning carried by eye-movement and perhaps thoracic pressure."

(G) "After series had gone on for a little while I got notion of movement in arc, large loops between terminals, carried by thoracic pressure and eye movement."

(G) "At first two perfectly discrete touches, did not think of object making them. After series ran awhile got movement between the two points. Principal thing was eye-movement, tracing arc in imagery."

(3) When the movement is in or on the skin the perceptions appear to be of a different kind; the meaning is inferred from the pressure sensations themselves, and the existential correlate seems to be a spatial and temporal integration of pressure.

(D) "Seemed to slide along skin..... a rapid peripheral extension of the pressure quality."

(G) "Slid on skin, change in extent of experience in time."

Summary

(1) We discovered in the Preliminary Experiments, which were undertaken to identify the 'bow' movement and to determine the optimal conditions under which it appeared, (*a*) that our objective conditions were alone not adequate to the perception of movement; (*b*) that we were

dealing with a perception which is in part dependent upon subjective conditions; and (*c*) that we should have to establish the 'meaning' attitude if we wished to continue the investigation.

(2) We found in the Main Experiments, in which we endeavored to establish the necessary attitude indirectly by rapidly repeating the bimembral stimulus, and by asking in the instructions for reports of process as well as for reports of meaning, (*a*) that various kinds and types of movement, unimembral, bimembral and full, were reported by all the *O*s; (*b*) that the optimal condition for the arousal of the perception varied greatly from *O* to *O*; and (*c*) that the diversities as well as the uniformities in the results of the different *O*s indicate that the perception of bow-movement haptically aroused is not primarily dependent upon objective conditions. The essential requirements seem to be that the *O*s shall have the idea of movement and that this idea be given time for realisation.

(3) The analysis of the introspective reports corroborates these conclusions. (*a*) The perception is gradually built up; (*b*) the arc, loop, or bow movement is a meaning added to the primary pressure sensations; and (*c*) the processes which carry this meaning are associated visual and kinaesthetic images, or incipient sensations.

(4) When the movement is in or on the skin the perceptions appear to be of a different kind. The meaning is inferred from the pressure sensations themselves, and the existential correlate seems to be a spatial and temporal integration of pressure.